International Journal of Engineering Education Vol. 31, No. 1(B), pp. 267–281, 2015
Printed in Great Britain
0949-149X/91 $3.00+0.00

Collaborative Technologies in Global Engineering: New Competencies and Challenges*

MATS DANIELS and ÅSA CAJANDER
Department of Information Technology, Uppsala University, Uppsala, Sweden. E-mail: mats.daniels@it.uu.se, asa.cajander@it.uu.se

TONY CLEAR
Computer and Mathematical Sciences, Auckland University of Technology, Auckland, NZ 1020, New Zealand.
E-mail: tony.clear@aut.ac.nz

ROGER McDERMOTT
School of Computing Science and Digital Media, Robert Gordon University, Aberdeen, UK. E-mail: roger.mcdermott@rgu.ac.uk

Educational institutions face many challenges in closing the gap between what is currently offered through academic engineering curricula and what is expected by society in general and industry in particular. There are many aspects to these challenges and here we address needs that are specific to global professionals by investigating the knowledge, skills and abilities needed for mediating and using Collaborative Technologies (CT) in an Open Ended Group Project (OEGP) within a global setting. We discuss these needs as framed by relevant theoretical frameworks for collaboration and learning (including Collaborative knowledge building and Collaborative Technology Fit), mapped using empirical data from a course setting involving global collaboration between two Universities (one in the United States and one in Sweden). The paper concludes with a commentary on competencies beyond discipline specific technical skills and presents recommendations, based upon this research, for developing students' proficiency in both mediating and using CTs in OEGP courses. These recommendations are followed by an outline of key areas for future research.

Keywords: collaborative technologies; professional competencies; open ended group projects, global collaboration, engineering education research

1. Introduction

The demand from society on educational institutions delivering engineering degree programs has shifted considerably towards competencies that lie outside mere technical skills. One example of such societal attention is the current (2012/2013) national evaluation of engineering degree programs in Sweden. Criteria for success in this evaluation include graduates meeting learning goals such as the "ability to critically discuss phenomena, issues and situations", "ability to carry on a dialogue with different groups" and "ability to make judgements based on relevant societal and ethical aspects". It has become evident from the evaluation that many educational institutions are far from successful in meeting such criteria. An underlying factor for this deficiency is the strong focus in engineering education on "well-structured (closed) problems" where the task is to come up with the right/best answer [1]. The students receive little practice in handling "ill-structured (open-ended) problems", which typically include both technical and non-technical competencies (*note that we consider the competence to configure technology for use as non-technical if it involves an understanding of aspects outside the "purely" technical*). The situation is compounded by a common attitude among students—and faculty—that anything beyond concrete technical competence is not really important and what matters, is to come up with one correct answer to a problem [1]. Furthermore, there is an uncertainty among teachers about how to integrate, teach and assess the non-technical competencies [2].

We address this gap between desired learning outcomes and today's traditional educational settings. We use a model for social knowledge-building [3] to identify important aspects in the process of developing non-technical competencies. The model illuminates the processes involved in creating functioning learning environments which address more general competencies than the narrowly technical and discipline specific. This is a wide area and we focus on use of Collaborative Technologies (CTs) in global collaboration in order to narrow the field and yet be relevant to our aim.

Our starting point is a study where we reflect upon students' shaping and use of CTs in a course where the students collaborate over the Atlantic Ocean. Our study maps such activities within the theoretical framework of "Collaborative Technology Fit" [4]. This study shows that the students were lacking in their capability to effectively shape and use CTs to meet the demands of global collaboration. Reflecting on the results of the study through the lens of Stahl's model for social knowledge-building [3]

* Accepted 15 July 2014.

provides insights into where problems arise. These insights are used to identify where the difficulties lie, e.g. which are the challenges that students needed to overcome and which are the competencies beyond the technical that students needed to master in mediating the use of CT. With this in mind, we discuss approaches suitable for addressing how to improve the needed competencies in this course, including identifying and evaluating some appropriate strategies for scaffolding the underlying "discovery learning" [5] approach. The proposed strategies for scaffolding are based on the observations in this study and rely on theories such as Constructive Controversy [6], Personal Epistemologies [7], Communities of Practice [8], Open-Ended Group Projects [9], and Student Contributing Pedagogy [10].

Addressing how to set up functioning learning environments for the development of non-technical competencies is a complex and ill understood endeavour. We present some approaches related to developing competence in the "use of CT in global collaboration". The setting and scaffolding discussed is also applicable for the development of learning environments targeting other non-technical competencies.

2. Global collaboration

The importance of non-technical competencies is increasingly evident as the work of engineers and computing professionals becomes more globalised [11]. Such work extends beyond participation in multidisciplinary teams, to work within globally distributed and intercultural projects. In this setting collaborative technologies (CT) [12] are crucial enablers of global developments, but their effectiveness is highly dependent upon the roles assumed and the activities involved in mediating the use of CT to support teams in their work [4].

These roles need to be consciously explicated and specifically developed, in particular to develop skills for collaborating in a global professional setting. In a discussion of the capabilities considered critical for professional software developers, Acuna and Juristo present a list of desirable attributes when assigning developer roles [13]. The list includes the following:

> Analysis, Decision Making, Independence, Innovation/Creativity, Judgement, Tenacity, Stress Tolerance, Self-organization, Risk Management, Environmental Knowledge, Discipline, Environmental Orientation, Customer Service, Negotiating Skills, Empathy, Sociability, Teamwork/co-operation, Co-worker evaluation, Group Leadership, Planning and Organization.

Surprisingly, while applicable in general, none of these attributes appear to specifically consider the globally distributed team setting. As the ACM taskforce has reported [11], there are new sets of capabilities demanded of professionals who will go on to work in these globalised contexts. Skills in mediating the use of technology, global team work and communicating effectively across barriers of distance, time, organisation and culture, all become important [14, 15].

As observed by Olson and Olson [16] collaboration across distance is complex and requires addressing the following three key dimensions: *establishing common ground*, *ensuring collaboration readiness* and developing *technology readiness*. CTs often provide complex and highly configurable platforms within which global teams may work. Understanding the ways in which such platforms are selected and established, as well as how group patterns of use evolve, are vital elements in a global team context. These processes of "technology-use mediation" (TUM) [17] can lead to successful or unsuccessful "appropriations" [18] of CT. In an earlier study [19] one of the students reflected upon the importance of CT in these terms:

> "I don't think this project would exist without the communication tools available to us"

Yet despite the common rhetoric of today's students being supposedly tech-savvy, "digital natives" [20], in our study it is observed that students used complex collaborative platforms less than optimally and:

> " . . . that the demands of technology use mediation imposed by collaborative technologies were not appreciated by students with prior experience of more personalized technology use" [19].

Moreover, it is noticeable that students have little understanding of the impact the choice of technology has on their collaboration. Despite being so-called "digital natives", they assume that the collaboration is unaffected by technology and they see technology as transparent and neutral [19].

Central to the functioning of geographically distributed collaboration is the creation of "common ground" between global team members, i.e. establishing "mutual knowledge", as addressed in a paper by Cramton [21]. Mutual knowledge can be established through (1) *Direct knowledge* created in first hand experiences, (2) *Interactional dynamics*, where it is created through any kind of interaction (although it should be remembered that uniquely held information, as opposed to commonly held information, is much less likely to surface in interactions [22]), and (3) *Category membership*, where assumptions on another team member's knowledge is based on social categorization [23], (e.g. a cabdriver is assumed to know how to get to the airport). Establishing such mutual knowledge, in a distributed collaboration in which only the last two are available, is not an easy task. There are difficulties in conveying nuances when compared to face-to-face meetings [24] and these are exacerbated by the fact that CT communication is slower [25]. Cramton identifies a number of problems that contribute to difficulties in establishing this mutual knowledge: failure to communicate and retain contextual information, unevenly distributed information, communicating and understanding the salience of information, differences in speed of access to information, and a particular problem being the difficulty interpreting the meaning of silence. She also points out that the difficulties are accentuated by the fact that the collaborators often are unaware of these problems.

2.1 Technology-use mediation

This, and other challenges, reflect the fact that information technology (IT) does not exist as a pure entity within a vacuum, but needs first to be adapted for and then adopted within a context of use. The process of technology-use mediation [17] refers to the activities associated with establishing a technology platform, embedding patterns of usage through both making adjustments to fit the setting and reinforcement of IT use, and subsequently engaging in episodic change where the IT platform is periodically modified at specific junctures to overcome manifest deficiencies or to suit new ends. For collaborative technologies in particular, these activities assume greater significance as patterns of collaborative behavior as opposed to mere individual adoption need to be encouraged, in tandem with productive patterns of IT use. In global virtual collaborations these technology-use mediation roles are assumed in part by the coordinators and faculty running the course, on both a local and global basis, and may often include support from other information or education technology professionals. The process of aligning these several dimensions has been discussed in [4, 26], where the theory of "Collaborative Technology Fit" has been introduced and applied in globally distributed project settings. The tools applied from this work have enabled students to reflect in some depth about specific instances of collaborative technology use and a lack of collaborative technology fit across sites. These misalignments had been occasioned by a combination of technology incompatibilities and misunderstandings coupled with unconscious cultural assumptions and behaviours [4, 27]. Students can be led to consciously reflect upon their roles and the activities associated with technology-use mediation as in [27], where the reflections came somewhat after the fact. The challenges with global collaboration using CTs lie in designing educational activities so that this consciousness is explicitly developed from the outset, and in ensuring a suitable level of scaffolding so that students can not only effectively use the CT platforms themselves, but more importantly mediate their use for other team members. This demands that students learn how to establish the platforms to encourage collaborative teamwork (not individual use, or simple partitioning of the tasks [28]), and how to adjust the technology and reinforce productive patterns of use.

2.2 Educational setting

Educational settings with global collaboration are thus highly suited to address development of student capabilities that go beyond mere technical skills. We present a study demonstrating how a cohort of American and Swedish students at the end of their respective degree programs used CT in a global project set in the health sector with a real client. The educational setting is based on theories for adopting "Open-Ended Group Projects" (OEGP) [9] as a pedagogic approach. The course aims to address deficiencies in the preparation of tomorrow's engineers by the provision of an authentic global learning experience, where we consciously include learning opportunities related to the development of intercultural competence. As stated in an earlier review of the course:

> "A goal of the IT in Society course is that the students should be able to constructively participate in a project dealing with a complex and multifaceted problem set in a real environment" [9].

The rationale for our study is that Information Technology and in particular the proliferation of CT is a critical enabler of global collaboration across the boundaries of distance and time and that mastery of CTs in a global team setting is central to the competencies outside their discipline specific technical skills that the engineering graduates are expected to possess.

3. Collaborative technology (CT) usage patterns

3.1 Method

The survey data was analysed to identify the frequency and perceived value of use of particular CTs and the ratings which students assigned them.

The reflection was a compulsory written exercise answered by all students in the course. The task was to reflect on the positive and negative aspects of the different communication technologies used in the project. Data was thematically analyzed [29] to identify positive and negative statements regarding the use of collaborative technologies and their embedded features.

Supplementing these analyses was a "Collaborative Technology Fit" [4, 27] mapping of the open source platform "Teamlabs". This mapping involved identifying the interplay of six dimensions in operation at each site as they impacted on the use of "Teamlabs" as the chosen technology "metastructure" of focus for the analysis. By viewing these dimensions in combination i.e. the *technology* in focus; the *institutional* forces in operation; the *actions taken by individuals* in the setting; the forms of *technology-use mediation* [TUM] *actions* taken; the aspects of *technology use* and the *cultural* dimensions that bear on the chosen 'metastructure' (as the analytical unit) at each site, a cross-site interpretation of the degree of CTF or alignment at each site is possible. The "Collaborative Technology Fit—Teamlabs" section below demonstrates this comparison for the "Teamlabs" platform (www.teamlabs.com).

3.2 Survey data analysis

As noted previously students were surveyed mid way through the course to gauge (among other things) their perceptions of the CTs being employed to support their collaboration. The results of the survey are summarised in the chart in Fig. 1 below, depicting the CT used, the most common frequency of its use (or in one case the perceived value of the CT), and the rating assigned by students.

Note: for ease of comparison, usage and rating data are normalised to a percentage rather than the original rating against a five point likert scale

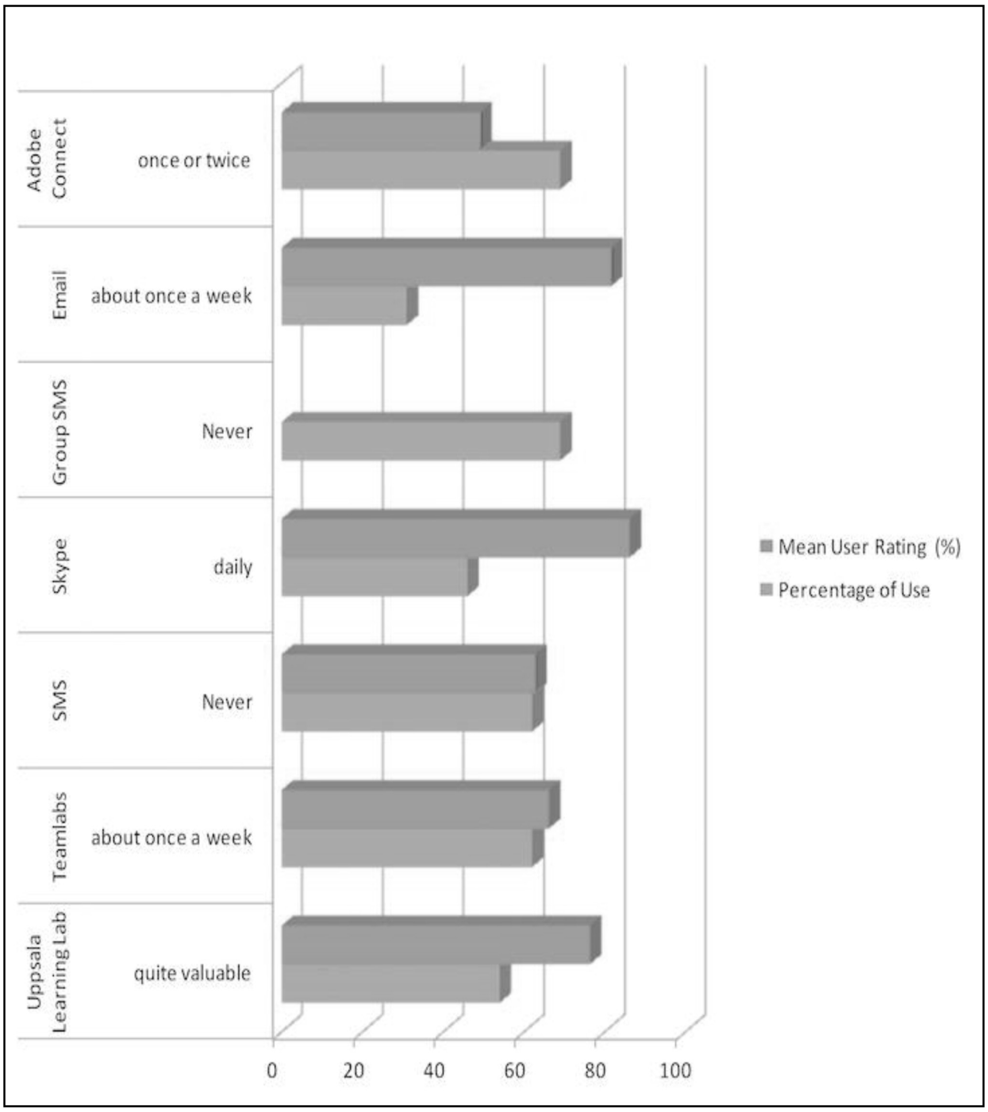


Fig. 1. Collaborative Technologies: Predominant Frequency of Use and Ratings (from questionnaires, n = 13)

(from respectively: *never* to *several times a day*; and *more or less useless* to *highly functional*).

As can be seen the most highly rated CTs were *email*, *Skype* and the *ULL facility* (the ULL facility is Uppsala Learning Lab and is a well supported and well equipped communication room). The latter judgement is surprising since *Adobe Connect* video-conferencing was the primary CT used in the ULL setting, and it was only used once or twice and rated by 53% of the students at levels 1 and 2 of the 5 point likert scale where 1 was *more or less useless*. However this rating was occasioned by significant technical difficulties when joint sessions were plagued by loss of sound and video connections. The rating of the ULL by contrast seemed to value the physical space as a good actual and potential setting for whole group communication. The most frequently used CTs were *Skype* with *daily* use being most common, and *email* and *Teamlabs* at *about once a week*. Thus the patterns suggest a combination of CTs being used at differing regularities for complementary purposes, which will be explored in the next section.

3.3 Student Reflections Data Analysis

Again at a midpoint in the course, students completed a brief reflective assignment, in which they considered the positive and negative features of the collaborative technologies they had used. This data proved a rich source of specific information about how they had used the different CTs and their features. This data thus gave a more detailed insight into the specific CTs and features, their uses both singly and in combination, and the challenges that students had encountered in using them. The reflections for each student were analysed thematically by CT and feature, and by isolating the positive and negative statements related to the technology.

Appendix A provides a full tabulation of the CTs and their features, analysed by student. The table quantifies the number of positive and negative statements made about each CT, which are frequently broken down to particular feature level (e.g. voice for *Skype*, document sharing for *Teamlabs*). This analysis complements that in Fig. 1 and is starkly illustrative of the diverse patterns of use and preference and shows the broad range of CTs and features in operation. A statistical T-Test of the summary columns of pros and cons for each site showed a significant difference in usage patterns across sites (at the 0.03 level for 'pro' statements and 0.02 level for 'con' statements).

From Appendix A we can build a more in depth picture of patterns of technology use, which recognise that some CTs are not single technologies but rather incorporate a range of features. Relevant to this discussion is the notion of *appropriation*, or the way in which users of technology select certain *structures* or *features* for use, and adopt them in particular ways. For instance despite a view of today's learners as "digital natives" [20] or the web 2.0 "zapping" generation [30] teams did not elect to adopt common social software such as Facebook, blogs or twitter. Yet the CTs that teams appear to have most commonly adopted are a wider set than identified in the above survey responses. In addition to Adobe Connect, email, Skype, Teamlabs and ULL, we see use of Google Docs, Google Groups, Google Calendar, phones and cell phones, face to face local meetings (as a substitution or complement to the CTs in use), and some use of text messaging by cell phone or via Instant Messaging as a feature of Skype.

To the extent that students appropriate the software in common ways, regular patterns of use will become established. DeSanctis& Poole [18] have observed that:

> "appropriations of the technology are evidenced as a group judges whether or not to use certain features of an IT product such as a GSS [Group Support System—such as "Teamlabs"], directly uses (reproduces) a structure, or blends or interprets a structure in some way".

The impact of this activity is to help establish regular patterns of use:

> "GDSS structures become stabilised in group interaction if the group appropriates them in a consistent way, reproducing them in a similar form over time" [18].

A notable feature of the usage patterns that evolved were the particular combinations of CTs that teams adopted. As one team member observed: "*Each program allows us to easily handle one subject. Together they make a fairly cohesive whole*."

- Commonly teams used *Skype* for synchronous communication, with the *text chat* or *IM* feature enabled to support a continuous dialogue across sites, and also to support asynchronous discussion when other team members were not available.
- In some cases *SkypeIM* substituted for *email* use, but email was typically used to communicate across sites and teams, with *Google Groups* sometimes used for broadcast email messages. It appears that responsiveness to email was an issue for many, with overload a possible cause.
- *Teamlabs* was used for sharing documents at team and project levels, frequently in combination with Google Docs for preparing documents collaboratively at local or sub-team level prior to posting to the common space. In addition Teamlabs was used by team and project leaders for project management—task and milestone setting

and time tracking, with team members posting their time data to the site. A fuller discussion of Teamlabs use is given below.

- *Adobe Connect* and the *ULL* were used for introductory whole cohort meetings with videoconferencing and PowerPoint sharing being used, but appeared to be plagued by connectivity problems with frustrating loss of audio and voice. This led one team leader to observe "*When our group ran into issues with Adobe Connect J and I made an executive decision to move the whole team over to Skype for better reliability*". We see here an example of "Technology-use Mediation" [17] where the team leaders undertook an *episodic change* activity in response to a technology "breakdown" [31], by substituting an initially established CT platform with a more effective alternative. Yet there were deficiencies with Skype noted by the students, among them "*the lack of [group] video without paying for Skype premium. This didn't really affect the work or communication but would have been nice to have*". This action can also be regarded as an example of "compensatory adaptation" [32], where it is argued that people who are motivated enough to achieve a goal will overcompensate for deficiencies in the media available to them. The theory of compensatory adaptation therefore has been argued to overcome some of the weaknesses in media richness theory [32].
- At the local or sub-team level, additional patterns of use were reported—*face to face meetings*, use of *phone*, *cell phone* and *text messages* to augment other forms of communication and information sharing at global or project levels. For instance phone calls and follow up emails were used to contact "*external people for interviews and such because it is harder for them to ignore a call than it is an email*". These patterns had not been apparent from the survey data.
- Features that were not adopted included the *Teamlabs Calendar* option that was introduced late, after many teams had already become familiar with *Google Calendar*. Similarly the *forum* and *chat* features of Teamlabs were not used, seemingly due to local patterns of CT use which saw no need for these features and as one student commented "*a resistance among project members to introduce another communication tool, as it would increase the complexity of communicating*".

Thus we see patterns of use developing in which a unique combination of CTs were used to achieve the goals for each sub-team, which resulted in variable intersections between practices at the sub-team and global team levels. One notably pragmatic student observation on criteria for the choice of software was "*does it work? and how long does it take to set up?*" with the added comment that "*in this project it's more important to get something that works fast rather than something that's perfect*". One reflection captured neatly the earlier discussion about the appropriation of CTs to establish stable patterns of group interaction with the technology:

> "I think collaboration and the use of communication tools within a group is something that develops over time, as individuals try different successful and unsuccessful ways of communicating they learn to find efficient ways in the end. Throughout this progress a shared understanding for how to communicate and collaborate is developed within the entire project".

3.4 Collaborative Technology Fit—Teamlabs

The analyses above had highlighted a few differing usage patterns and challenges with the *Teamlabs* platform, had indicated that it had been actively adopted by students and teams across both sites, and shown some successful and unsuccessful practices of technology-use mediation at local and global team levels. Therefore, to complement the above analyses, the *Teamlabs* CT (as a feature rich and configurable CT platform) was chosen as a *metastructure* (a "mediating institutional, cultural, or technology structure, which serves to shape [collaborative] technology use [4, 26]) through which to investigate the degree of 'collaborative technology fit' (CTF) across sites. Some key aspects in the dimensions of CTF at each site are tabulated below and then the degree of CTF across sites is portrayed in the radar charts of Fig. 2.

3.4.1 Rose Hulman

Technology—Teamlabs (document sharing, task setting, milestone setting, time tracking).

Institutional—Commitment to course as a globalisation initiative in collaboration, not clear whether videoconferencing facility available?

Individual Actions—Team members upload documents to Teamlabs, post time records to Teamlabs, team leaders create milestones, assign tasks, track progress.

TUM Actions—Team leaders assign milestones in Teamlabs, Teams and subteams post documents to a common single page, no organization of content by sub-team, no training in use of Teamlabs given, milestones not removed once completed, complementary face to face meetings held locally.

Technology Use– Team members upload documents to Teamlabs, teams use both googledocs and teamlabs for document sharing—results in confusion, usability issues with teamlabs—multiple places, levels and links, comfort with Teamlabs use grows over time, in one subteam googledocs used for individual document sharing at subteam level, completed versions posted to Teamlabs for whole team sharing, Teamlabs used in combination with other collaborative applications offsetting limitations.

Cultural—Team and subteam differences in practice (e.g. use of googledocs & Teamlabs in combination), the distributed situation does not feel personal and causes a lack of responsibility to the team, Skype use apparently not so common in the US

3.4.2 Uppsala

Technology—Teamlabs (as for Rose Hulman) plus calendar feature.

Institutional—Teamlabs (as for Rose Hulman) plus ULL facility provided as a support for international collaboration.

Individual Actions—Teamlabs (as for Rose Hulman) plus weekly team meetings address the need for tracking progress better for members?

TUM Actions—Addressing varying levels of use based on team tastes, some groups share all documents in area related to their group, others very few—not so simple as asking pressured team members to use Teamlabs more? A standard way of sharing material recommended? Project leaders assign milestones in Teamlabs, team leaders track time and progress, sort and categorize tasks and share information, Teams and subteams post documents to dedicated folders with organization of content by sub-team, no training in use of Teamlabs given, complementary face to face meetings held locally, if time tracking not demanded could have swapped Teamlabs document sharing for Dropbox? Calendar used as alternate to Google calendar but introduced late so not picked up, Chat and forum features not picked up.

Technology Use—Project leaders assign milestones in Teamlabs, team members upload documents as for Rose-Hulman, but use mostly for document sharing and time tracking (esp. by team leaders), usability issues with teamlabs—multiple places, levels and links—leads to reduced levels of use and some substitution by googledocs for document sharing, in other cases adopted fully and googledocs use drops off, Teamlabs used in combination as at Rose-Hulman.

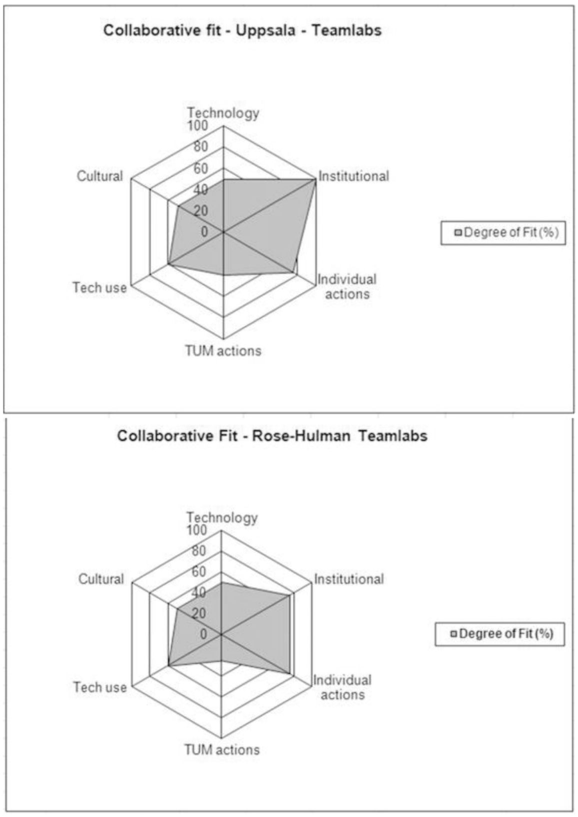
Cultural– Skype use apparently common in Sweden, varying levels of use of Teamlabs—hard to get greater buy-in when students are taking several courses, 6 hr time zone difference a challenge for meetings with four busy university students, communication occurs within smaller groups with own preference of collaborative technology.

As is evident from the tabulation of the CTF dimensions above and the patterns of CTF portrayed in Fig. 2, students demonstrated some similarities in patterns of use across sites. This could largely be expected since they were participating in common global teams. Overall, the Teamlabs technology has been judged to have achieved at least a ‘partial’ level of fit on most dimensions. The main dimensions in which it fell short were those of *TUM actions* and the *cultural* dimension.

The *cultural* dimension of CTF is certainly a challenging one for global collaborations, with the pressures inherent in ‘student culture’ bringing their own challenges. This also relates back to Cramton’s ‘mutual knowledge problem’ [21]. The issue was expressed by one student who noted the need to

> “adapt to the groups needs dynamically. For our group, our communication is far more inhibited by the time difference and distance than the collaboration software”.

The area of most limited alignment and therefore the most productive area for attention is in that of



Degree of Fit Scale (%)
100% - Full Collaborative Technology Fit
75% - Moderate Collaborative Technology Fit
50% - Partial Collaborative Technology Fit
25% - Limited Collaborative Technology Fit
0% - No Collaborative Technology Fit

Fig. 2. Collaborative Technology Fit Mapping – Uppsala and Rose-Hulman for *Teamlabs.*

*TUM action*s, where it is clear that some additional steps might have been effective in improving the collaboration process. TeamLabs was chosen by the students themselves as a collaborative platform, and one student described the choice in this way: "*They have a quite flashy introduction video, and I think that that is what caught everyone's interest*". The vast majority of the students had never used a project management tool before, and they reported that it initially took some considerable time to understand what they were supposed to use it for. Nonetheless students seem to have been able to generate patterns of technology use that were functional enough at the local or sub-team level. However, the awareness of and the need for structures that supported project and team leaders, and cross site and global activities was less likely to arise from a distributed model of self selected technology platforms and features. Perhaps a phase of defining the CT requirements at differing levels preceding a formal evaluation process and platform selection, followed by a more conscious process of training and standards setting for use of the CT at these more global levels, could have borne fruit.

4. General reflections on the CT usage patterns using a model for collaborative knowledge-building to discuss CT usage

4.1 Stahl's model of collaborative knowledge-building

In order to understand both the personal and social dimensions present in the development of competences, we find it useful to draw on Stahl's theory of Collaborative Knowledge-Building developed within the field of Computer-Supported Collaborative Learning. Drawing on the work of Brown and Duguid on Organizational Learning [33], and Lave and Wenger on Communities of Practice [34], Stahl's theory is an attempt:

> ". . . to understand learning as a social process incorporating multiple distinguishable phases that constitute a cycle of personal and social knowledge-building. The cyclical character of this process allows increasingly complex questions to be posed on the basis of more and more sophisticated understanding". [3]

While Stahl developed this model into a general theory of computer support for collaborative knowledge construction [35], we use it here as a conceptual foundation on which to build a description of the process by which growth in personal competence is situated within a social context.

In Stahl's model (see Fig. 3), the foundation of personal knowledge is tacit pre-understanding [36] which underpins individual and collective understanding, shaping our perception of the world, and from which we cannot really disengage. Under certain circumstances, elements of this understanding become problematic [37] and no longer fit into our experience. This conflict is resolved by a process of drawing out the implications of existing knowledge and reinterpreting structures of meaning to arrive at a new personal comprehension which becomes the basis of a new tacit understanding and so provides the starting point for future understanding and further learning [3].

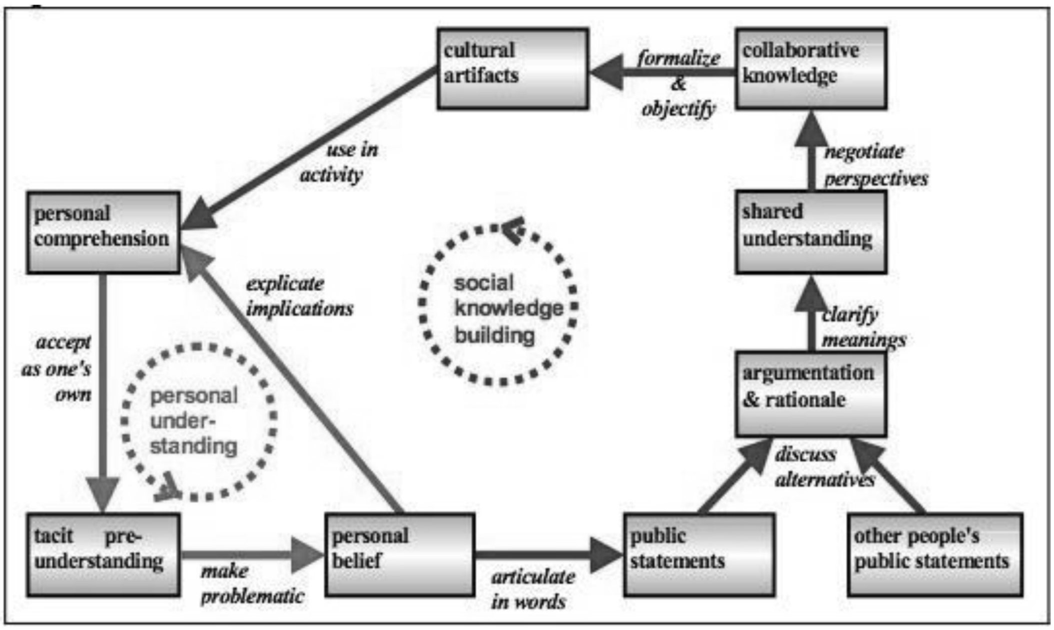


Fig. 3. Stahl's Model of Collaborative Knowledge-Building (from [3], p. 3).

It should be noted, however, that even this consideration of the growth in personal understanding includes a tacit consideration of the social dimension, involving as it does apprehension of external feedback in the form of the individual's experience with collaborative artefacts created. While personal beliefs arise based on an individual's personal perspectives, they are formed within a socio-cultural milieu which has a shared language and access to shared representations of knowledge. This leads to the creation of shared cultural objects that embody that knowledge and these objects are communicated through social interaction. While an individual belief may be a purely personal phenomenon, knowledge itself is a socially mediated product.

This is especially true if one considers the development of professional competencies which are usually acquired in some kind of collaborative environment. There is clearly some element of growth in personal understanding involved with such competencies, but this is almost always embedded in a matrix of social interaction which serves to clarify, moderate and reinforce the knowledge, attitudes and skills that are acquired and practiced. Whether this occurs in a classroom, a workplace environment or some kind of community of practice, the learning involves a variety of interpersonal processes such as discussion, negotiation and prioritisation which act to create what Stahl terms "social knowledge", and which in turn further moderates the growth in personal knowledge of the individuals themselves.

In order to understand both the individual and group aspects of learning, it is best to consider that the two cycles are in conjunction, where we see that individual insights and knowledge are tested and moderated by group interaction. According to Stahl, discussion of personal insights and knowledge allows individual views to be compared and contrasted with the stated positions of others which, through a process of critical analysis and argument, may allow for a shared understanding to emerge. This can then lead to an increase in the social knowledge held by the group, which can be validated by the construction and employment of artefacts that the group find valuable. Reflection on the use of these then acts as input into a further cycle of personal knowledge creation.

It is clear from Stahl's model that a key element in this process of social knowledge construction is the discussion and analysis of multiple individual viewpoints which leads on to the formation of a shared communal perspective. However, this itself is crucially dependent on the ability of individuals to clearly articulate their own views and insights. If, for whatever reason, individuals are not able to express their views to other members of the group, or if such expression is done in a limited way, or is generally perceived to have limited value, then this will lead to a lack of appropriate analysis and hence to lack of rigorous scrutiny of the subject matter. Lack of clarity concerning vocabulary may, for example, mean that important technical distinctions are lost, while an insufficient conceptual base may lead to a poor rationale for evaluation of alternatives, or for decisions concerning priorities. Under such circumstances, it would be extremely difficult for a shared understanding of the subject to emerge and, without this common perspective, collaborative knowledge-building is extremely difficult. Since a shallow communal understanding would be a poor foundation for collaborative knowledge, it is reasonable to expect that any artefacts created from this superficial approach would have a limited fitness for task. This would mean that their usefulness to the group would be relatively low and hence that individuals would find it difficult to appropriate them as valuable either personally or because of their contribution to group identity or performance. Since the quality of reflection is closely linked to perceptions of value (which, in turn, are closely tied to individual impressions of utility), this would tend to reduce the importance of the social knowledge construction cycle considered as an input into the personal knowledge development cycle, and so further progression would be inhibited.

4.2 Observed patterns of CT usage

The pattern of students' collaborative technology use that was observed in the project was somewhat surprising and, in terms of the elements of the theory outlined above, it would be expected to have a significant impact on their learning. From the data collected, it appears that there was little attempt by individuals to articulate considered personal beliefs about technology use to other members of the group and little personal reflection on the non-technical aspects of the project. Given their high levels of technical proficiency, one might expect to see the students show similar levels of competence in the non-technical aspects of the project. However a minimal level of articulation concerning the use of technology was observed which suggested that the implications for communication of the different choices of CT were effectively invisible to the students themselves. Indeed, it was unclear whether the subsequent use of a particular CT was based on subjective individual preferences or whether the choice to employ a technology simply emerges through a desire to avoid conflict within the group.

While this issue of the apparent "invisibility" of the technology to students may be surprising, there are established pedagogical models which shed some light on the situation. In their investigation into the ways in which information technology artefacts are understood, Orlikowski and Iacono [38] suggested four different perspectives on information systems: the *tool* view, the *computational* view, the *proxy* view and the *ensemble* view. The most common view is the *tool* view which sees technology as a means of processing information so as to enhance productivity or affect social structures. Such technology is seen as a relatively unproblematic resource and emphasis is placed on the objects which are transformed by the action of technology rather than the concrete mechanism by which that occurs. A related perspective is the *computational* view which sees technology primarily as a means of manipulating information either through implementation of appropriate algorithms or through the simulation of external phenomena based on some computational representation. The underlying assumption in this view is that technological effectiveness is essentially a matter of finding the correct computational model. In both these cases, the focus of attention lies outside the technology itself, either on the specific outputs of its use, or on the abstract procedures which helped to generate them. The *proxy* view attempts to determine a set of metrics (such as the rate of uptake, usability, social or economic capital) which it seeks to use as representative measures to gauge the critical aspects of the technology's effectiveness. Finally the *ensemble* view is one in which the technology is seen as one element in a complex set of social processes aimed at accomplishing some allocated task, and its investigation necessarily involves an analysis of the wider sociological factors associated with its use. In both these latter two cases, purely technical considerations form one element in a more general analysis, and the conception of technology is one in which a more mutually shaping process between technology and use is involved.

As pointed out by Clear [39], a key distinction here is the role of context. The *computational* and *tool* views emphasise the role of technology as a means of developing knowledge through abstraction. Unfortunately, this divorces the analysis from the concrete situation in which the individuals and the technology operate. technology is merely applied to achieve goals in a setting By contrast, the *proxy* and *ensemble* views are much more context-dependent, and accommodate an understanding of technology which is centred on how it is applied in realistic situations, and in turn how it shapes behaviour through somewhat recursive processes. According to Clear, a mature understanding of technology would entail a perspective that is able to integrate, or at least acknowledge, all the views of technology described by Orlikowski. It appears reasonable to infer that the students in this study were too focussed on a view of technology as tool or computational process rather than the more embedded notions implicit in the proxy or ensemble views. This had implications for the value they placed in decisions about the need to consciously configure the technology platforms that were employed in order to shape and reinforce positive patterns of use. As a result this impacted negatively on their ability to satisfy the learning objectives that were related to these factors. Although individuals may have made some progress in their own learning, they failed to do so effectively. They could not access the social dimensions of knowledge-building as they were unable to effectively articulate the reasons for the choices they made.

5. Setting up a learning environment suitable for building CT use competence

We will address setting up a learning environment from two perspectives, the first being about making the issue of using CT appropriately important and the other being suggesting a concrete approach to constructively discuss the use of CT. The issue of motivation is quite complex and it is crucial in that it is one of the strongest forces for learning [40, 41]. An inventory of the personal epistemologies of the students is a useful approach to get a base for understanding how to motivate them. An important aspect of motivation is that the students feel that they "own" the problem, which is a central ingredient in the Open-Ended Group Project concept [9] and is well illustrated in the literature on Student Contributing Pedagogy [10]. Further insights into motivation can be found in the work by Lave and Wenger on Communities of Practice [8]. The concrete approach is based on Constructive Controversy [6]. We will expand on these issues and relate them to Stahl's model of building social knowledge [3].

5.1 Constructive controversy as strategy

There is no silver bullet to set up a learning environment for improving the students competence in using CT in a global collaboration. The complexity of the task, as described, is too high for this, but we suggest that our analysis of previous incarnations of the course indicates that a lack of discourse around technology use (mediation) is a major problem. Relating to Stahl's model this can be described as the arrow "articulate in words" is missing (or at least weak), which has negative consequences for the building of a shared understanding of CT use. The constructive controversy theory [6] provides a suitable tool to address this.

The constructive controversy theory can be briefly described as first introducing a controversy by presenting alternatives and then ask the participant to use the presented alternatives to construct a solution to the controversy based on seriously considering the presented alternatives. The following six stages have been identified as related to constructive controversy [42]:

1. Students are assigned problem/decision, initial conclusion.
2. Students present and listen, are confronted with opposing position.
3. Students experience uncertainty, cognitive conflict, disequilibrium.
4. Cooperative controversy.
5. Epistemic curiosity, information search.
6. Incorporation of new information, adaptation to diverse perspectives, new conclusion.

5.1.1 Articulate in words

To articulate in words has been identified as barely happening in our study. The OEGP setting in itself could provide excellent motivation for discussing CT use, but this require that the students see this as important. Our conjecture is that the community of practice, that the students form, assumes CT use as something they master and need not discuss. A study of their personal epistemology would provide valuable insights into this conjecture. We see a need to scaffold the students into discussing both mediation and direct uses of CT. The two first stages in constructive controversy provide a good setting for this. The students could for instance be assigned to propose different CT and platform configuration options as the means for their collaboration.

5.1.2 Discuss alternatives and clarify meanings

The low appearance of articulation obviously leads to little or no discussion and clarification of meanings. The discussion there was hampered by a lack of common vocabulary and a low appreciation of importance of non-technical aspects of the CT use. Stages three, four, and five in the constructive controversy approach can provide valuable support to discussion and clarification. The articulation of issues, if coupled with an increased appreciation for their importance for CT use, should provide a need to know more and to find ways to address the conflicts regarding CT use illuminated by presentations of alternative solutions. The task could be to come up with a joint and well argued strategy for CT use in the collaboration, where choices should be clearly motivated. The complexity of such a task would lead to much uncertainty, a further need for information, and not least cooperation. An understanding of the workings of communities of practice and the personal epistemology of the students are valuable ingredients in scaffolding these stages.

5.1.3 Negotiate perspectives

The negotiation of CT use was not a visible process, it was more the case that patterns of use emerged without any articulation, or after only rudimentary argumentation. This is related to the adaptation to diverse perspectives in stage six above. To negotiate in a constructive manner is a challenge and scaffolding in a constructive controversy assignment could be a much needed support for the students.

5.1.4 Formalize and use

The students obviously used CT and through this built social knowledge regarding this, but lack of formalization made this much less effective. These steps can be seen to complement the negotiate perspective step as the sixth stage of constructive controversy. Asking the students to reflect on their decisions and the actual use of CT would help them solidify their CT use competence.

5.1.5 Valuing non-technical aspects

Stahl's model functions well as a guide to build scaffolding in the complex issue of mediating CT use constructively in a global collaboration. That much of the complexity is due to non-technical aspects is a complication when it comes to engineering students. It is important to address the issue of the students taking these aspects seriously and ideas from Students Contributing Pedagogy [10] can be quite useful in achieving this, especially if consideration to the value aspect [43] is considered.

6. Discussions

To effectively establish and use Collaborative Technology (CT) in a global collaboration is an example of the important non-technical competencies that are sought after in the workplace and are complicated to set up learning environments for. Such a competence is composed of a complex set of skills, which in itself presents a learning obstacle for the students. This obstacle is compounded by both students and faculty having a tendency to devalue non-technical aspects of a problem. A major challenge is thus to make students, as well as faculty, value their development of non-technical skills related to this competence.

We have analysed a student collaboration with the Collaborative Technology Fit (CTF) model [4] and did find that the students indeed had severe problems with mastering this competence. The students showed limited awareness of the need for communication and information sharing structures that would support project and team leaders, and cross site and global activities. This resulted in high variability of CT use and a very confused picture of activities and information at levels above that of the individual student and local team. The well supported ULL facility proved of limited value to many students when the video conferencing technology turned out to be unreliable, and this was with dedicated and technically capable staff mediating the use of technology. Navigating technology "breakdowns" [31] and "displaying a phlegmatic response to crises" [44] appear to be key skills in global collaboration.

The decision to leave open to assumed 'tech savvy' students to select the appropriate technology and mediate its use needs some rethinking. It seems that the form of 'tech savviness' possessed by students using social networking technologies, i.e. abilities related to individual technology user engaged with pre-configured personal consumer devices or services in a 'mass-customisation' model [45], is not enough with regard to the skills required for large scale global collaboration.

A deeper understanding and focus on the technology-use mediation activities which are demanded to support the work of groups and global teams is necessary. We propose using Stahl's model for social knowledge-building [3] as a means to achieve these goals and exemplify how the scaffolding in the learning environment intended for developing the competence can be improved. Our example also illustrates that the use of theories, such as Constructive Controversy and Communities of Practice, can complement Stahl's model in this endeavour.

A pedagogical challenge is that adding scaffolding is contrary to the essentially problem based or discovery learning setting of the course. That is, to what extent should this opportunity be constrained? As Mayer has noted [5, 46] guiding a problem in an overly prescriptive manner may restrict a student's freedom to become cognitively active in the process of sense making and may therefore limit their ability to go beyond the simple prescribed task. However, the high complexity, e.g. the need for a global framework and a set of standards for information and communication sharing, means that a purely student driven process informed by an individual or a local team perspective is unlikely to prove optimal. There is also the issue of generalizing ideas to new problems and several studies [5, 46] have found that guided discovery is more effective than unguided discovery in terms of achieving this. An example of guidelines for a guided discovery task is proposed in [46], (1) caution against unwittingly introducing unplanned complexity; (2) advocate recognising the negative learning implications of constrained as opposed to more open ended tasks; and (3) recommend that an approach of scaffolding with guided discovery be adopted.

One option for future consideration would be the development of a rubric or evaluation sheet to help other colleagues to evaluate students' acquisition of such competence, based in some way upon the elements of Fig. 2. This need has been previously identified with work being required to further calibrate the scales in the CTF model "to more reliably determine the degree of fit" [4]. Such a rubric could also be based on the approach of [13], augmented with some indicators and levels to help measuring.

Finally, our example is limited to setting up a learning environment for one non-technical competence. It is however, possible to apply the general reasoning in this paper, e.g. use of Stahl's model and other learning related theories, to other competencies.

7. Conclusions

The examples in this study illustrate that our technology skilled students are lacking in competencies of crucial importance for functioning in global engineering settings. Rigorous investigations illustrate deficiencies in how the students establish and mediate the use of Collaborative Technology. Stahl's model of Collaborative Knowledge-Building provides insights into constructing learning environments addressing these problems. The Constructive Controversy theory is offered as a framework to set up such learning environments. Our example shows the value of engineering education research in learning how to meet the challenges of new demands on our engineers, as their workplace becomes increasingly globalised and in need of competencies beyond the solely technical.

References

1. J. Rick and M. Guzdial, Situating Coweb: A Scholarship of Application, *International Journal of Computer-Supported Collaborative Learning*, **1**, 2006, pp. 89–115.
2. L. McKenzie, M. Trevisan, D. Davies and S. Beyerlein, Capstone design courses and assessment: A national study, *ASEE Annual Conference*, Salt Lake City, 2004.
3. G. Stahl, A Model of Collaborative Knowledge-Building, *4th International Conference of the Learning Sciences*, Mahwah, 2000, pp. 70–77.
4. T. Clear and S. MacDonell, Understanding technology use in global virtual teams: Research methodologies and methods, *Information and Software Technology*, **53**, 2011, pp. 994–1011.
5. R. Mayer, Should There be a Three Strikes Rule Against Pure Discovery Learning?—The Case for Guided Methods of Instruction, *American Psychologist*, **59**, 2004, pp. 14–19.
6. K. Smith, D. Johnson and R. Johnson, Can conflict be constructive? Controversy versus concurrence seeking in

learning groups, *Journal of Educational Psychology*, **73**(5), 1981, pp. 651–663.
7. B. Hofer and P. Pintrich, *Personal epistemology: The psychology of beliefs about knowledge and knowing*, Lawrence Erlbaum Associates, 2002.
8. E. Wenger, *Communities of Practice: Learning, Meaning, and Identity*, Cambridge University Press, 1998.
9. M. Daniels, Å. Cajander, A. Pears and T. Clear, Engineering Education Research in Practice: Evolving Use of Open Ended Group Projects as a Pedagogical Strategy for Developing Skills in Global Collaboration, *International Journal of Engineering Education*, **26**, 2010, pp. 795–806.
10. J. Hamer, Q. Cutts, J. Jackova, A. Luxton-Reilly, R. McCartney and H. Purchase, Contributing Student Pedagogy. *Inroads*, **40**(4), 2008, pp. 194–212.
11. W. Aspray, *Globalization and Offshoring of Software—A Report of the ACM Job Migration task Force*, ACM, New York, 2006.
12. R. Davison and G-J. De Vreede, Global Application of Collaborative Technologies: Introduction, *Communications of the ACM*, **44**(12), 2001, pp. 68–70.
13. S. Acuna and N. Juristo, Assigning People to Roles in Software Projects, *Software—Practice and Experience*, **34**(7), 2004, pp. 675–696.
14. A. Pears, Should We Care About Global Intercultural Collaboration? *Inroads*, **1**(3), 2010, pp. 4–7.
15. H. Holmstrom, E. Conchuir, P. Agerfalk and B. Fritzgerald, Global Software Development Challenges: A Case Study on Temporal, Geographical and Socio-Cultural Distance, *1st International Conference on Global Software Engineering*, Florianópolis, Brazil, 2006, pp. 3–11.
16. G. Olson and J. Olson, Distance Matters, *Human-Computer Interaction*, **15**(2), 2000, pp. 139–178.
17. W. Orlikowski, J. Yates, K. Okamura and M. Fujimoto, Shaping Electronic Communication: The Metastructuring of Technology in the Context of Use, *Organization Science*, **6**(4), 1995, pp. 423–444.
18. G. DeSanctis and M. Scott Poole, Capturing the Complexity in Advanced Technology Use: Adaptive Structuration Theory, *Organization Science*, **5**(2), 1994, pp. 121–147.
19. Å. Cajander, M. Daniels, M. Cullhed, T. Clear, R. McDermott and C. Laxer, Categorizing How Students Use Collaborative Technologies in a Globally Distributed Project, *42nd ASEE/IEEE Frontiers in Education*, Seattle, 2012, pp. 1325–1330.
20. M. Prensky, Digital natives, digital immigrants, *On the Horizon*, **9**(5), 2001, pp. 1–6.
21. C. Cramton, The Mutual Knowledge Problem and Its Consequences for Dispersed Collaboration, *Organization Science*, **12**(3), 2001, pp. 346–371.
22. G. Strasser and D. Stewart, The discovery of hidden profiles by decision-making groups: Solving a problem versus making a judgment. *Journal of Personality and Social Psychology*, **63**, 1992, pp. 426–434.
23. R. Krauss and S. Fussel, Mutual knowledge and communicative effectiveness, *Intellectual Teamwork: Social and Technological Foundations of Cooperative Work*, J. Gallagher, R. Kraut, and C. Egido, Eds, Hillsdale, NJ, USA: Lawrence Erlbaum Associates, 1990, pp 111–146.
24. R. Hightower and L. Sayyed, The impact of computer-mediated communication systems on biased group discussion, *Computers in Organizational Behavior*, **11**(1), 1995, pp. 33–44.
25. S. Straus, Technology, group process, and group outcomes: Testing the connections in computer-mediated and face-to-face groups. *Human Computer Interaction*, **12**(3), 1997, pp. 227–266.
26. Å. Cajander, T. Clear, M. Daniels, J. Edlund, P. Hamrin, C. Laxer, and M. Persson, Students analyzing their collaboration in an international open ended group project, *39th ASEE/IEEE Frontiers in Education Conference*, San Antonio, 2009, pp. M1D1-M1D6
27. Å. Cajander, T. Clear and M. Daniels, Introducing an External Mentor in an International Open Ended Group Project, *39th ASEE/IEEE Frontiers in Education Conference*, San Antonio, Texas, 2009, pp. T2D1–T2D6.
28. W. Waite, M. Jackson, A. Diwan and P. Leonardi, Student Culture vs. Group Work in Computer Science, *ACM SIGCSE Bulletin*, **36**(1), 2004, pp. 12–16.
29. D. Ezzy, *Qualitative analysis: Practice and innovation*, Crows Nest, NSW, Australia: Allen & Unwin, 2002.
30. H. Selg, Swedish Students Online: An Inquiry into Differing Cultures on the Internet, *Youth Culture and Net Culture: Online Social Practices*, E. Dunkels, G-M. Frånberg, and C. Hällgren, Eds. Hershey, NY, USA: Information Science Reference, 2011.
31. M. Hettinga, Understanding evolutionary use of groupware, *Doctoral Dissertation, TelematicaInstituut, Delft University of Technology*, Enschede, 2002.
32. N. Kock, Compensatory Adaptation to a Lean Medium: An Action Research Investigation of Electronic Communication in Process Improvement Groups, *IEEE Transactions on Professional Communication*, **44**(4), 2001, pp. 267–285.
33. J. Brown and P. Duguid, Organizational learning and communities-of-practice: Toward a unified view of working, learning, and innovation, *Organization Science*, **2**(1), 1991, pp. 40–57.
34. J. Lave and E. Wenger, *Situated learning: Legitimate peripheral participation*, Cambridge, UK: Cambridge University Press, 1991.
35. G. Stahl, *Group cognition: Computer support for building collaborative knowledge*, Cambridge, MA, USA: MIT Press, 2006.
36. M. Polanyi, *Personal Knowledge*, London, UK: Routledge and Kegan Paul, 1962.
37. J. Dewey and A. Bentley, *Knowing and the known*, John Dewey: The later works, 1925–1953 (Vol. 16), J. A. Boydston (Ed.), Carbondale, Il, USA: SIU Press, 1949/1991.
38. W. Orlikowski and C. Iacono, Research Commentary: Desperately seeking the "IT" in IT Research—a Call to Theorizing the IT Artifact, *Information Systems Research*, **12**(2), 2001, pp. 121–134.
39. T. Clear, Information Technology Postgraduate Education: Professional Partnerships versus Discipline Silos? [Online Journal]. *The Pantaneto Forum* (8), 2002, pp 1–5.
40. T. Clear and D. Kassabova, Motivational Patterns in Virtual Team Collaboration, *Conferences in Research and Practice in Information Technology*, **42**, 2005, pp. 51–58.
41. R. Ryan and E. Deci, Intrinsic and Extrinsic Motivations: Classic Definitions and New Directions, *Contemporary Educational Psychology,* **25**(1), 2000, pp. 54–67.
42. D. Johnson and R. Johnson, Energizing learning: The instructional power of conflict, *Educational Researcher*, **38**(1), 2009, pp. 37–51.
43. Å. Cajander, M. Daniels and R. McDermott, On valuing peers: theories of learning and intercultural competence, *Computer Science Education*, **22**(4), 2012, pp. 319–342.
44. S. Jarvenpaa and D. Leidner, Communication and Trust in Global Virtual Teams, *Organization Science*, **10**, 1999, pp. 791–815.
45. T. Clear, E-Learning: A Vehicle for Transformation or Trojan Horse for Enterprise?—Revisiting the role of Public Higher Education Institutions, *International Journal on E-Learning*, **1**, October–December 2002, pp. 15–21.
46. A. Philpott, T. Clear and J. Whalley, Understanding Student Performance on an Algorithm Simulation Task: Implications for Guided Learning, *ACM SIGCSE Bulletin*, **41**(1), 2009, pp. 408–412.

Reflections #2 - Analysis	Uppsala Members Statements																						Uppsala Sum		Rose Hulman Members Statements														Rose Hulman Sum	
Stud. Id:	3		5		6		7		8		9		11		12		13		14		15				1		2		4		10		16		17		18			
Collab Technologies and Features	pro	con	pro	con	pro	con	pro	con	pro	con	pro	con	pro	con	pro	con	pro	con	pro	con	pro	con	pro	con	pro	con	pro	con	pro	con	pro	con	pro	con	pro	con	pro	con	pro	con
Adobe Connect	1	1	2	1	3	1		3	3	5		1	2	2		1	1	1	1	3	3	2	**16**	**21**		2	1	2					1	2			1	5	**3**	**11**
Adobe Connect desktop sharing	1																						**1**	**0**			1												**1**	**0**
Adobe Connect ppoint sharing	1										1				1								**3**	**0**															**0**	**0**
Adobe Connect sound/audio	1				1	2		1							1					2		1	**3**	**6**									2					1	**2**	**1**
Adobe Connect - group video	1				3	1		1			1				1						1	1	**7**	**3**									3					1	**3**	**1**
Cellphone			1																		1	1	**2**	**1**															**0**	**0**
Cell-phone texting/sms											1										1	1	**2**	**1**															**0**	**0**
DropBox	1		1		1												1						**4**	**0**															**0**	**0**
E-mail	3	2	1		1	3			3		5	4	2	2									**15**	**11**			1	2	2		1		1						**5**	**2**
Google Calendar					2	2										1							**2**	**3**															**0**	**0**
Google Docs	5	3	4		1				5		1		2	1	3	3	3	4	1	1	2	3	**27**	**15**			4	1	1	1			2		4	1	3	2	**14**	**5**
Google Docs - shared slideshow																							**0**	**0**													1		**1**	**0**
Google Groups													1	1									**1**	**1**			4												**4**	**0**
IRC chat																				2			**0**	**2**															**0**	**0**
Laptop/computer															1								**1**	**0**															**0**	**0**
Latex	1																						**1**	**0**															**0**	**0**
Local face-to-face conversation	1									1													**1**	**1**			1						3		2				**6**	**0**
Powerpoint																					1		**1**	**0**	1														**1**	**0**
Skype	3	4	3		2		2		2		4	3	4	3	1	2	3		3	1	3	2	**30**	**15**			1			3	1	1	1	2	3	1			**6**	**7**
Skype - File sharing							1			1													**1**	**1**				1											**0**	**1**
Skype -IM			3	1	2		1				1		1		2				1				**11**	**1**				2			4	1	1		1				**6**	**3**
Skype -Microphone												2			1	1							**1**	**3**			2	1				1							**2**	**2**
Skype sound/audio				1	3				1		2		1	1					1	1			**8**	**3**			1				3		2						**6**	**0**
Skype - group video						2				1	1			1	2			1					**3**	**5**							1		3						**4**	**0**
Skype-Pro									1	1		1		1									**1**	**3**															**0**	**0**
Skype-Pro (Screen sharing)										1		1		1									**0**	**3**															**0**	**0**
Skype-voice chat																							**0**	**0**											1				**1**	**0**
Skype - web cam																							**0**	**0**															**0**	**0**
SVN/version control system							1										2						**3**	**0**															**0**	**0**
Teamlabs	3	3	2		2	4		3		3	2	2	1	2	2		2	2	3	1	2	1	**19**	**21**			4	3	1	3		2	2						**7**	**8**
Teamlabs- calendar												1			2								**2**	**1**															**0**	**0**
Teamlabs- chat & forum														3									**0**	**3**															**0**	**0**
Teamlabs- document sharing			1	1	1						1			1	2	1	1	1			1		**7**	**4**			1	1			1				4	1			**6**	**2**
Teamlabs- task setting			1	1							2										1		**4**	**1**							1								**1**	**0**
Teamlabs- milestone setting			1	1							1										1		**3**	**1**				2											**0**	**2**
Teamlabs- time tracking			1	1							3												**4**	**1**							2								**2**	**0**
Teamlabs/Google Hosts																1							**0**	**1**															**0**	**0**
Telephone	2	2								1													**2**	**3**															**0**	**0**
Telephone-calls											3	1											**3**	**1**					1				2	2					**3**	**2**
Uppsala Learning Lab					1						1												**2**	**0**															**0**	**0**
Windows Live Messenger															1								**1**	**0**															**0**	**0**
Yahoo Messenger															1								**1**	**0**															**0**	**0**
	24	**15**	**21**	**7**	**23**	**15**	**5**	**8**	**15**	**14**	**30**	**16**	**14**	**19**	**21**	**10**	**13**	**9**	**10**	**11**	**17**	**12**	**193**	**136**	**1**	**2**	**21**	**15**	**5**	**7**	**14**	**5**	**23**	**6**	**15**	**3**	**5**	**9**	**84**	**47**

Mats Daniels is a senior lecturer and director of undergraduate studies at the Department of Information Technology, Uppsala University, Sweden. Mats is also director of the national centre for pedagogical development in technology education in a societal and student oriented context (CeTUSS, www.cetuss.se) and future site coordinator for the ACM ITiCSE conference. He also served as chair for the IEEE Nordic Education Society Chapter when it was awarded the first IEEE Education chapter achievement award 2006. His ambition when it comes to education is to find new formats and especially such where the students will experience a holistic learning environment, e.g. in Open Ended Group Projects.

Åsa Cajander is associate professor in Human-Computer Interaction (HCI). Her research in HCI has focused on usability of IT in government organizations and health care, and on teaching and learning of HCI. In the former area she have been an action researcher in a large number of projects focusing on software development processes, and especially on user centred systems design. In the latter area her research has focused on improving education with a special interest in professional competences relevant for students in the field of HCI.

Tony Clear is an Associate Professor with the School of Computer and Mathematical Sciences at Auckland University of Technology, New Zealand. His research interests are in Software Engineering Education Research, Collaborative Computing and Global Software Engineering. Tony holds positions as a Column Editor and Associate Editor for *ACM Inroads*; Editorial Board member for *Computer Science Education,* has been co-chair for *Australasian Computer Science Week 2014, is Panel & Posters chair for International Conference on Global Software Engineering 2014* and program co-chair *Innovation and Technology in Computer Science Education Conference 2014*.

Roger McDermott is senior lecturer in Computing and Mathematics, and Undergraduate Programme Leader, in the School of Computing Science and Digital Media at the Robert Gordon University, Aberdeen, UK. He teaches computer scientist and engineers. His research interests include theories of learning, the teaching of professional skills, and the epistemology of computing and engineering students.